Extremely Lightweight Mirrors for Space Applications

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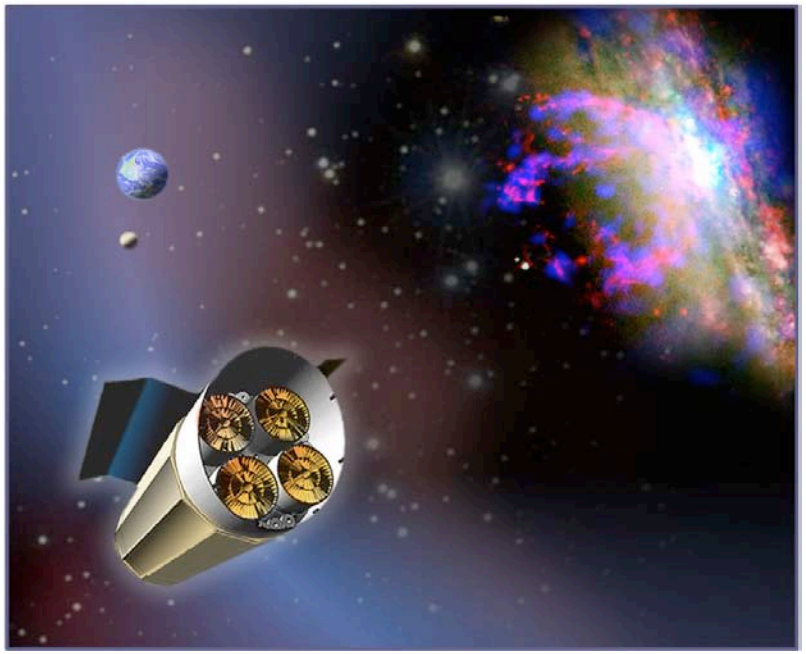
Constellation-X Mission

constellation-x.gsfc.nasa.gov

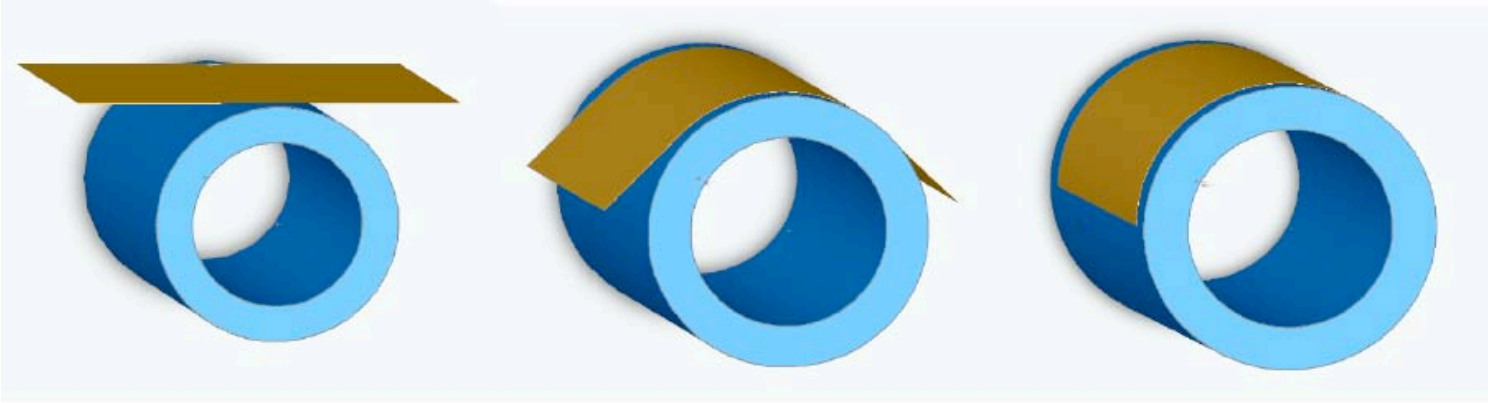


- NASA's next major X-ray observatory
- Carrying four identical telescopes
  - Focal length: 10m
  - Diameter: 1.6m
- Studying black holes, dark matter, chemical evolution, general relativity, etc.

Salient Features of These Mirrors

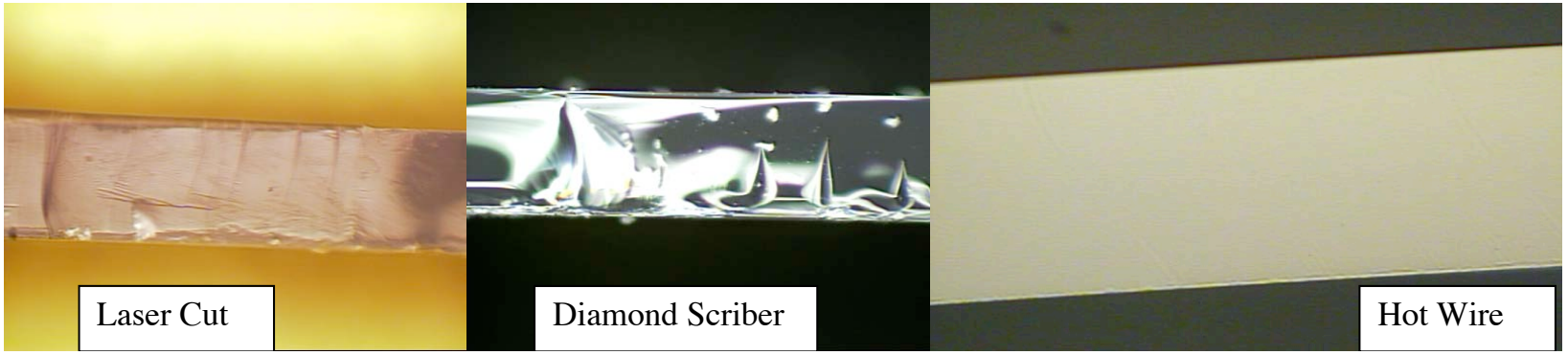
- Extremely lightweight: areal density less than 1 kg/m^2
- Diffraction limited: figure error $\lambda/20$ (RMS) at 6328Å
- Excellent microroghness: <5Å RMS
- Production cost significantly lower than that of conventionally produced mirrors

The forming process



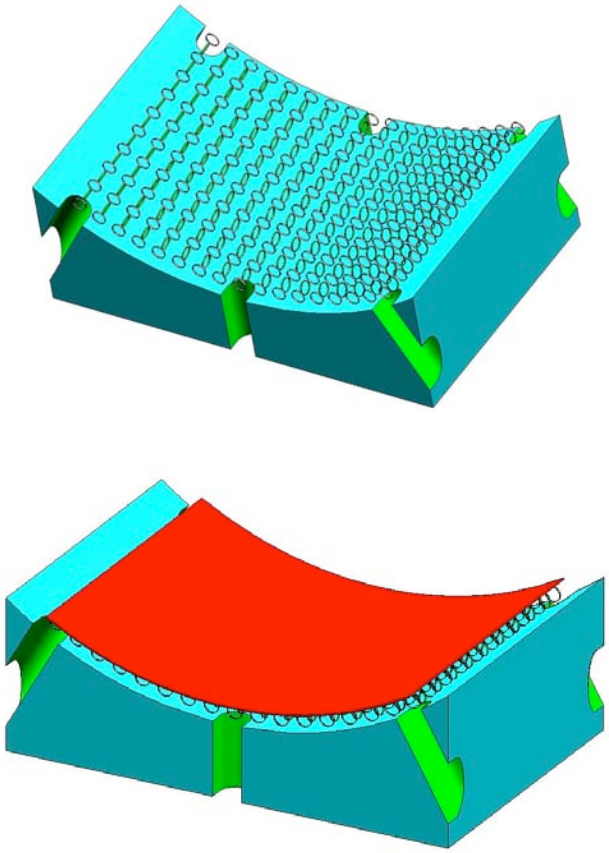
- Schott D263 glass sheets, 0.4mm in thickness, 2.5 g/cc in density
- Heated in an electric oven with good temperature uniformity
- Slow heating to maintain good thermal equilibrium
- Slow cooling to ensure proper annealing
- Post-slumping trimming to remove edges

Post-forming trimming



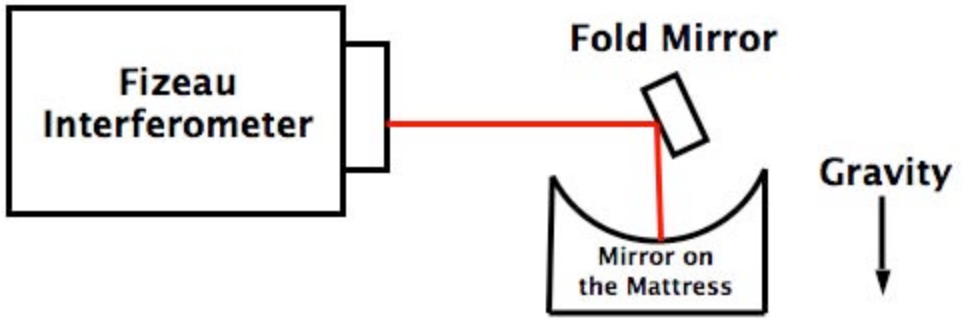
- To remove edges that are not properly formed
- To cut mirror to size
- To remove micro-fractures on those edges

Mirror Support and Handling



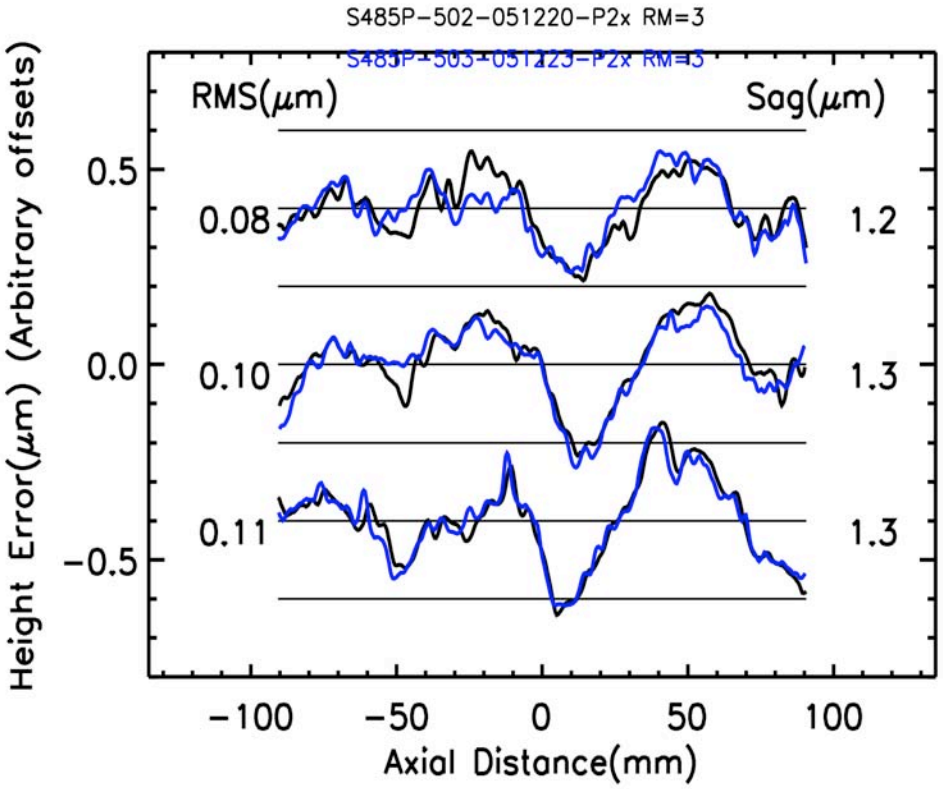
- To simulate a gravity-free environment
- To serve as a mirror transporter, allowing it to be handled and moved with minimal distortion

The Metrology Process



- To measure the mirror along the direction of its symmetry axis
- To scan to whole surface of the mirror by rotating the fold mirror around the mirror's symmetry axis

A Deterministic Process



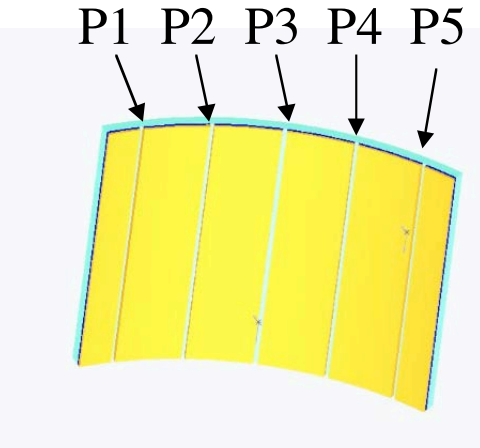
Necessary Conditions to Have Repeatability

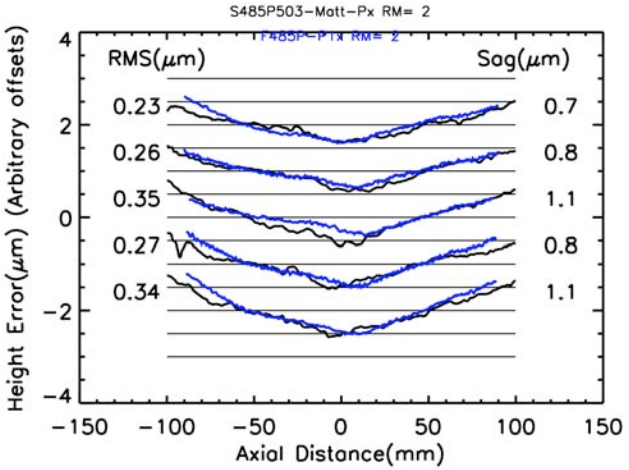
- Forming has to be good
- Metrology registration has to be good
- Distortion has to be very small or nearly identical

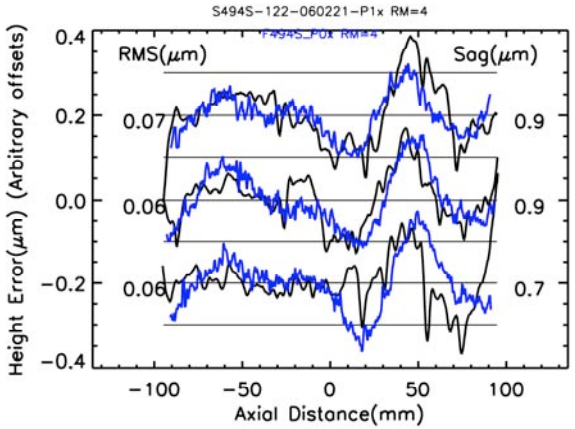
Best: 21nm RMS Typical: 50nm RMS

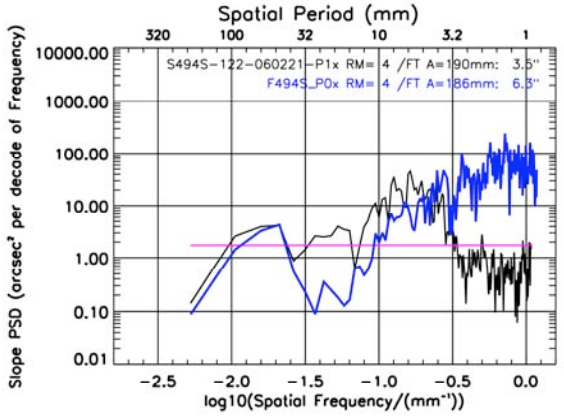
These numbers are most likely dominated by a lack of accurate cross registration, therefore should be considered as upper limits

Axial Figure Measurements

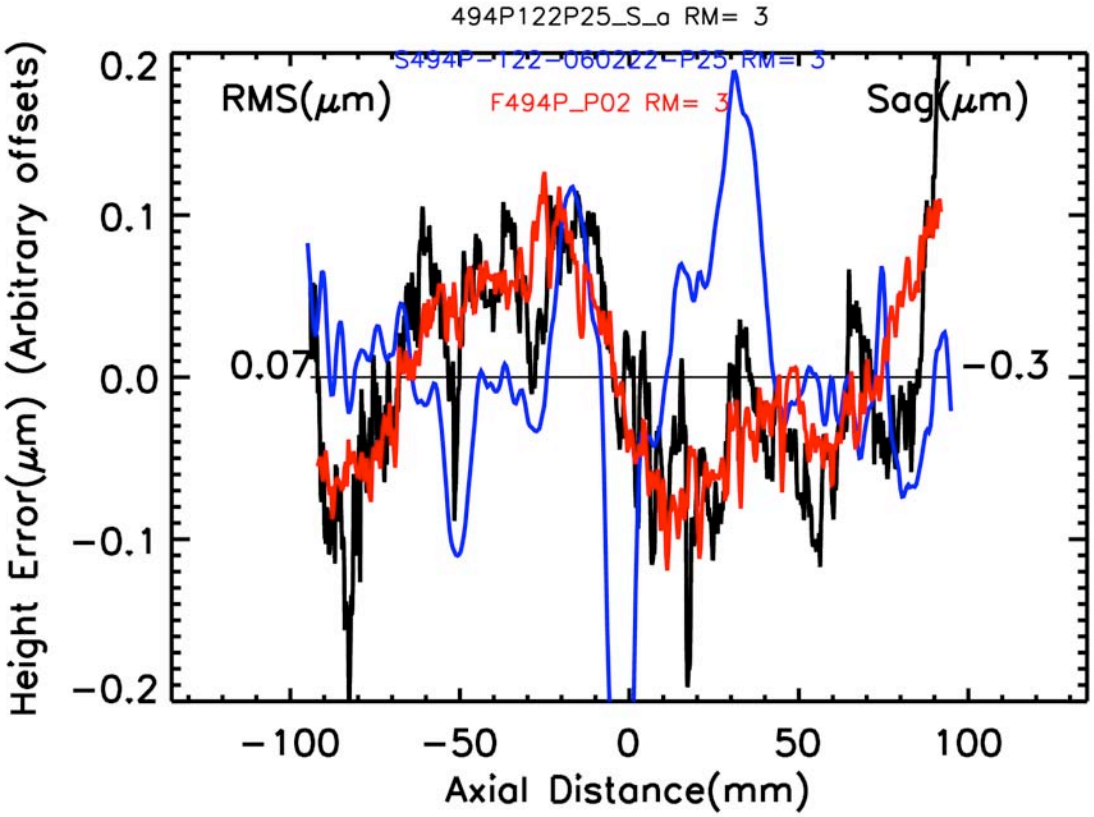








How Accurate Is the Forming Process?



Applications

- Future X-ray telescopes: Con-X and a number of SMEX and MIDEX missions
- Future space telescopes: large aperture normal incidence telescopes
- Large ground-based normal incidence telescopes
- ……